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Greenhithe Boys' School, Kent

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RAMBLES AMONG OUR INDUSTRIES

There was a wise custom of the old trade guilds, the "wander-year", when the apprentice, having served his time, spent a year in wandering from one master to another before settling to his trade. The aim of the wander-year was to broaden the knowledge of the young tradesman and teach him the dignity of his craft. A like purpose has led the publishers to add to their "Rambler" Series a number of books dealing with the main industries of the country. It is well that boys and girls, before passing out into the busy life of the world, should learn something of the reality and something of the romance of the great industries by which that life is sustained.

CONTENTS

CHAP.		Page
I.	THE "GARDEN OF ENGLAND"	5
II.	THE FIRST "BINDING" MATERIAL	9
III.	LIME-BURNING	15
IV.	THE HISTORY OF CEMENT	21
V.	ARTIFICIAL PORTLAND CEMENT	28
VI.	THE CHALK QUARRY	32
VII.	CLAY-DIGGING	37
VIII.	THE WASH-MILLS	40
IX.	THE KILNS	49
X.	THE GRINDING-MILLS	57
XI.	THE LABORATORY	63
XII.	EVERYDAY USES OF PORTLAND CEMENT	71

LIME AND CEMENT

CHAPTER I

The "Garden of England"

"In Kent 'tis cherry time,
Or hops are picking."

Browning.

I do not suppose there is any county whose early history is so closely bound up, and identified with that of England for nearly two thousand years as Kent. Indeed, for many centuries the history of Kent has been the history of England.

As we turn over its pages we come across such names as Julius Cæsar, St. Augustine, Hengist and Horsa, Earl Godwin, Thomas à Becket, King Stephen, Wat Tyler, Jack Cade, Sir Philip Sydney, General Wolfe, and Sir John French, to mention only a few. All of them have been associated with Kent, and all have played their part in the making of England.

Kent, however, has other claims upon our notice. It is an agricultural county, and a tour through its orchards and hop fields would convince you that it is really the "Garden of England".

It is also the home of certain very important industries. The Arsenal at Woolwich, the paper-mills at Sittingbourne and other places, and the dockyards at Sheerness and Chatham occur to us at once. But there is another industry which is perhaps not so well known outside the county as those I have mentioned, which gives employment to thousands and thousands of work-people, and that is the making of lime and cement.

To get some idea of the area in which this industry is carried on, let us sail down the Thames, starting from Dartford Creek. As we enter Long Reach, the banks of the river become very flat and uninteresting. You will notice, however, that for mile after mile the low chalk hills and cliffs on each side have been quarried and cut away, and the chalk removed. You will also notice a succession of dusty, grey-looking factories, from which seems to spring a forest of tall shafts or chimneys.

Though you may find the river banks dull and uninteresting to some extent, the same cannot be said of the river itself, for there is a ceaseless stream of traffic. Boats and ships of all kinds pass us, some hurrying up, and some down. Very possibly those which will interest you as much as any will be some low, deeply-laden barges creeping up with the tide, making for the factories to which I have just drawn your attention, and which we still continue to pass. And their cargoes? Well, not fruit or hops, but something not nearly so inviting; simply dirty, blue-

looking clay. Mud, it is sometimes called locally, while the boats themselves are often called mud-barges. But it is not mud, though it looks very much like it. As you will find later on, there is a great difference between mud and clay.

Map of the Cement Area

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Perhaps you will see one of the barges drop its sail, and come to anchor beside the jetty or wharf attached to a factory, and there it will discharge its cargo of clay.

However, let us continue our journey, for we are anxious to see as much as we can of the "cement area". We pass Greenhithe, Northfleet, Gravesend, Cliffe, on the south side of the river, and Purfleet, Thurrock, Grays, and Tilbury on the north side,

A Clay Barge on the Thames

and at length arrive at the mouth of the Medway, the lower reaches of which, almost as far as Chatham, are rather dreary and desolate. At the same time, this is a very important district to the cement-maker, for it is here that the barges come for their cargoes of clay.

We now follow the Medway and sail past Chatham and Rochester, and here again, almost under the shadow of the old castle, we see on both banks of the river the same kind of factories as we saw when sailing down the Thames. It is not until we are close to Maidstone that we finally lose sight of them.

As far as the making of Portland cement is concerned, no purpose will be served by continuing our journey beyond Maidstone, for we should then pass out of the cement district and into that of hops and orchards.

So, as I want to show you how cement and lime are made and used, let us leave our boat and visit a factory where we can watch the process. With this object in view, I could not take you to a better place than one of these Thames or Medway factories, for, as I shall show you a little later on, I am taking you right into the birthplace and home of the industry. There are many other places in England where cement is made, the Isle of Wight, Bedfordshire, Cardiff, and Tyneside being some of the most important. It is also made abroad in Belgium, France, Germany, and the United States; but we like to think that the Portland cement of our own country is the best.

CHAPTER II

The First "Binding" Material

If you watch a bricklayer building a wall, you will notice that between each brick and its neighbour he very carefully places a layer of mortar or cement. This hardens or sets in the course of time, and binds the bricks together. Similarly, a carpenter uses glue as his binding material.

The man who first discovered a binding material that would withstand the action of the weather and not crumble away is not known, but he is almost worthy to rank equally with that other unknown discoverer who, perhaps quite by chance, first introduced the use of iron towards the end of the Bronze Age. It may be that both discoveries, like that of glass, were accidental.

We can easily picture to ourselves how the discovery of lime came about. Perhaps some humble prehistoric man, deprived of his cave dwelling, and anxious to protect himself and his family from the wind and rain, would build himself a wall of flat stones or turf, and take shelter on the lee side of it. That would be his first step. Then four walls and a primitive roof laid on the branches of trees would follow. In Dorsetshire, and other parts of the country where stone is plentiful, walls are still made in the same rough manner. This arrangement might satisfy him for a time, but of course every wind that blew would find out the cracks and crevices, and the rain would soon make its way through the roof. So, his next step would be to stop the holes with earth or mud, or, better still, with clay. Then down comes the rain again, away goes his mud, and the work has to be repeated over and over again. We are reminded of Shakespeare's lines:

> "Imperious Cæsar, dead and turned to clay,
> Might stop a hole to keep the wind away."

Let us trust our imagination a little further. Suppose, in building up his rude stone fire-place one day, he chances upon a piece of *limestone* and uses that. His fire-place will not last him long, for the limestone will soon become calcined or burnt, forming what is called *quicklime*, that is, lime which is thirsting for water. When a boy drinks, he is said to "slake" his thirst; and so, when this burnt limestone, or quicklime, is mixed with water, it becomes *slaked* lime, and crumbles to a powder. Further, slaked lime mixed with sand and water forms mortar.

In the prehistoric dwelling of which we are thinking, it is easy to imagine water in some way or other being upset over the fire-place, and turning the quicklime into slaked lime. The rain would be sufficient to do it. The fact that the burnt stone turned to powder under the action of water would be sure to attract the attention of our unknown man, and would lead him to experiment with it. Sooner or later he is bound to try a handful of the new stuff instead of the old. He then makes two discoveries: first, that it does not crumble away like the clay he has been using hitherto; and secondly, that the rain does not wash it away. It is hard and lasting, and therefore, whenever he has a hole or a crevice to stop for the future, you may be sure that he will burn limestone and make some lime. So the great discovery of lime is made, and its importance, not only as a building material, but in numerous other directions, cannot well be over-estimated.

However, there are more than one kind of rock known as limestone. So, in the manufacture of Portland cement and lime, you must always bear in mind the fact that we are dealing only with that kind which we call Carbonate of Lime.

This limestone is found in two states or conditions, pure and impure.

You are quite familiar with *pure* carbonate of

Shells from a piece of Chalk (highly magnified)

lime, for you see it every day in the form of chalk or whitening. If you burnt white chalk such as we saw when passing down the Thames, or white marble, you would certainly get a white powder, but if you tried to use it in the form of mortar, you would find that it would stand the action of water and weather no better than mud or clay. It would crumble away just as easily.

Chalk is a soft rock composed almost entirely of very small shells—the shells of minute animals that once lived in the sea—and if you examine a piece of it under a microscope, you can see these shells distinctly. It is almost pure carbonate of lime, and during the process of burning, the carbonic acid gas which it

contains is driven off, and what is known as calcium oxide is left behind. This is what the builders call rich or "fatty" lime, and is quite unfitted for outside work, though it is used to some extent for internal work, such as white-washing ceilings.

Now let us consider the second condition in which limestone is found. In this case it is not pure carbonate of lime, and, when burnt, yields what is known as *hydraulic* lime. Of course you know that the word hydraulic has something to do with water, and so perhaps you will guess that this particular kind of lime is given this name because it will stand the action of water. Such limestones contain impurities, and it is these impurities which give them their value when used as mortar. They are found in the form of grey chalk under the white chalk in Kent, and also in various parts of the country, such as Derbyshire and Warwickshire which are rich in them. These limestones are of a greyer tint than the white chalk, so that it is evident that they contain some substance which is not present in ordinary chalk, and which not only accounts for the difference in colour, but enables them to resist the action of water. This substance has a very grand name, "silicate of alumina", but you would call it common clay.

Remember that clay is very different from mud. Mud is composed of the powder formed by the wearing away of sandstone, granite, or any stone of that sort, mixed with decayed vegetable or animal matter, and water.

There are one or two things I want you to remember in connection with clay. You all know that it feels greasy, and so you will expect limestone rocks that contain clay to feel greasy also. Let us refer to its other name again, silicate of alumina. The name itself shows us that clay is a compound of two substances, silica and alumina. If it possesses a very large proportion of silica, it is better adapted for making pottery than for making a binding material. For the latter purpose we require a clay that contains a fair proportion of alumina in addition to the silica.

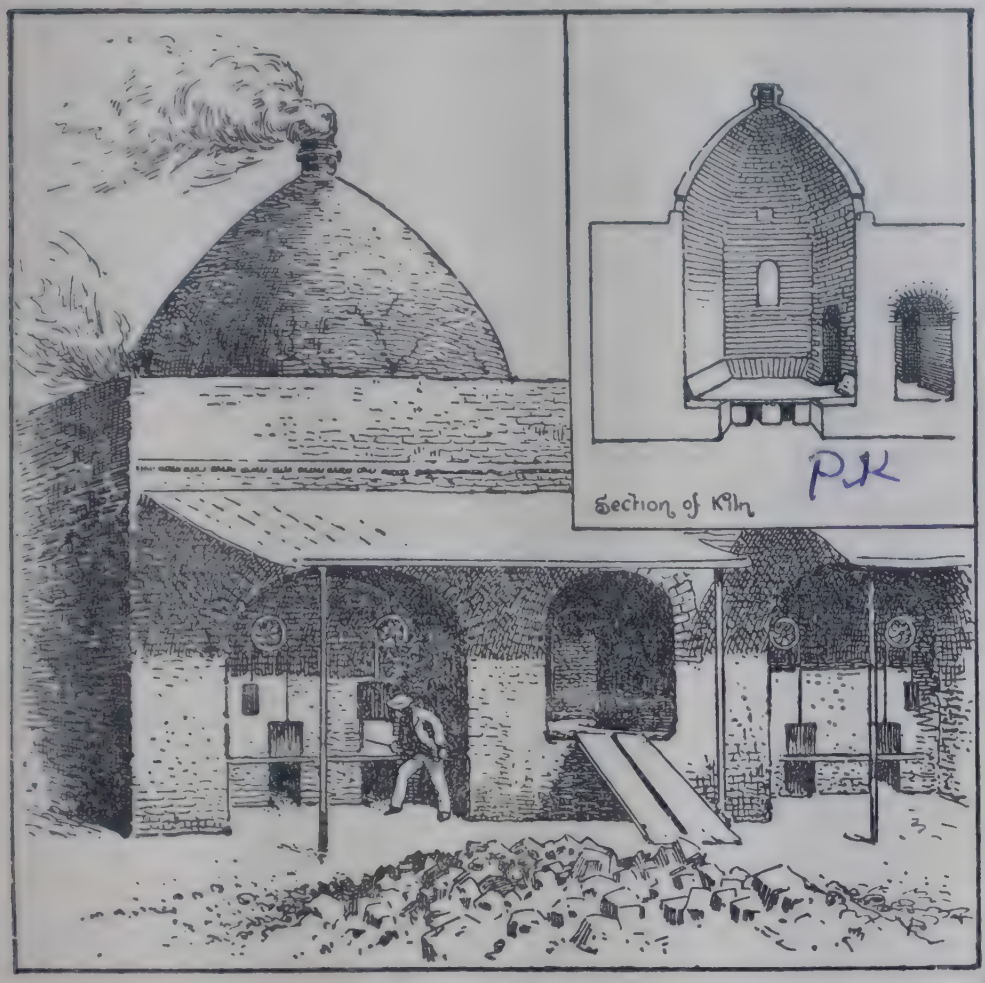
I have shown you that chalk is deficient in clay, but if you mix the two together in the right proportions, you have a mixture which, after going through certain processes, will yield a perfect binding material known as Portland cement.

Keep clearly before you the following facts:—

1. Pure limestone, i.e. limestone which contains no clay, or practically none, yields a lime which is useful chiefly for indoor purposes.

2. Impure limestone which contains a small percentage of clay, say ten to twenty per cent, yields a lime which is used in the form of mortar.

3. Impure limestone which contains still more clay, say twenty to thirty per cent, yields a hydraulic lime or natural cement.

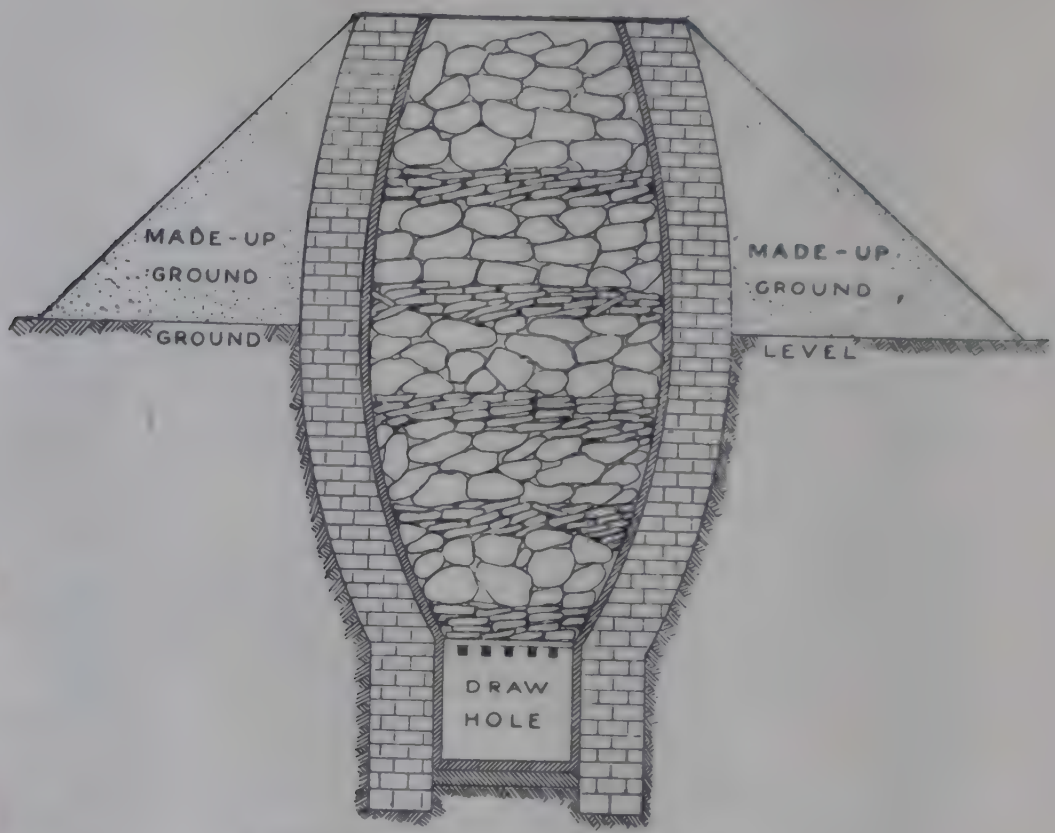


Lime or Cement Kiln

CHAPTER III

Lime-burning

Burning limestone is not by any means a difficult process. You could do it for yourself in an open fireplace or stove so long as you had sufficient heat to drive off the carbonic acid gas from it. Of course this method would be neither commercially nor economically satisfactory. So for the purposes of the builder

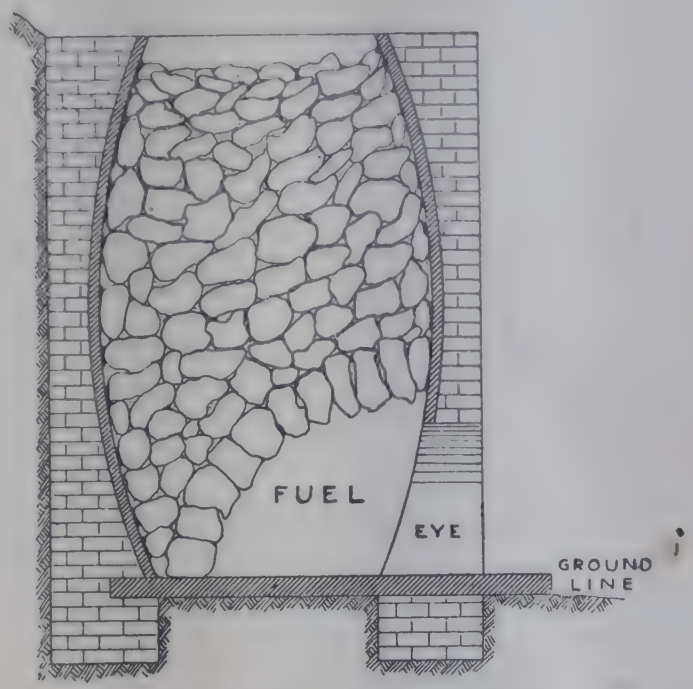


Section of a Continuous or "Running" Kiln

the limestone is burnt in specially constructed *kilns*, as they are called. These kilns in their primitive form—and that is the only form that will be dealt with here—were very simple in construction. They were effective, and are to some extent used to-day, though in somewhat modified forms. Still, the principle is the same.

Some of these kilns are worked continuously, the fire never being allowed to go out except for the purpose of repairs. For this reason they are sometimes called "running kilns". Here you have a section of a kiln of this description, showing clearly the method of filling it, and the grating on which

the fuel is placed, and through which the burnt lime falls into the draw-hole below. In loading this class of kiln, the limestone must be broken up into small pieces. When the burning process is finished the lime is withdrawn through small openings called "eyes". This is not the most economical kind of kiln, as it uses up a great quantity of fuel in the form of coke. Coke is preferred to coal because a purer and whiter lime is produced. Roughly speaking, to load a continuous kiln, you would require one part of fuel for every four parts of limestone. More modern kilns are so constructed as to burn five parts of limestone for one of fuel, thus proving more economical.



Section of a Flare or Periodic Kiln

Another class of kiln is not worked continuously. It is sometimes at work, and sometimes idle. So it is called "periodic". As it generally burns with a long flame appearing out of the top, it is often called more simply the "flare" kiln. After being loaded up, and the fire started, it is allowed to burn right out. It is shaped somewhat like a barrel, being wider in the middle than at the top and

bottom. It is also much shorter than the running kiln. There is a good reason for this particular shape. It allows the blocks of limestone to be placed in better position for burning, as you can see from a glance at the illustration; and further, a better draught is obtained, and the burning is more thorough. Also, less fuel is required. When beginning to load the kiln, the workman chooses fairly large blocks of limestone and these are built in the form of an arch over a framework or hearth of iron bars, which takes the place of the grating in the "running" kiln. In this arched cavity the fuel, consisting, if possible, of wood, is placed. One advantage of this form of kiln is that the ash does not mix with the lime, but on the other hand, it has the disadvantage that it consumes a great deal of fuel in proportion to the lime it produces. Both kinds of kiln are built of brickwork, and lined inside with fire-bricks.

When the limestone is sufficiently calcined, and all the carbonic acid gas driven off, it is allowed to cool down. This cooling process is rather wasteful as far as consumption of fuel is concerned. The iron bars are then drawn out so as to allow the lime to fall into the pit or recess beneath, from whence it is removed by the workmen. The kiln is then recharged and the process repeated from the beginning.

In more recent kilns the cavity formed by arching the limestone blocks is made of permanent brickwork.

Running and flare kilns have been used for a very

long time. Modern ones have been devised with a view to economizing fuel and labour, but the main principles involved are the same. The carbonic acid

Slaking Quicklime

gas must be driven off by heat, so that only pure calcium oxide, or quicklime, is left behind.

The quicklime must now be prepared so that it may be used as mortar. It must first be slaked, and I have already explained to you what that means. The builder does it by spreading out the lumps and sprinkling them with water until they have swelled as much as possible, and absorbed as much

water as they can. You will notice that while they are doing this, the lumps crumble into powder and develop great heat. This process sometimes takes several days.

Our builder might try to use the slaked lime itself for building, just as prehistoric man probably did. The result would be fairly satisfactory. There are several reasons why he does not do so, but the reasons you will understand best are that this method is too expensive, and that the addition of sand prevents undue shrinkage. So he mixes three or four parts of *sharp* sand, which is not expensive, with one of lime. This mixture is called *mortar*.

Other people, besides the builder, use lime in large quantities and for a variety of purposes. The farmer knows that it is a good manure, and uses it to clean and to enrich his land. The tanner finds it useful, for the skins which he buys to turn into leather come to him covered with pieces of fat and hair. Lime removes all that. In the same way, the glue manufacturer uses it to clean the horns, hoofs, and clippings of hide out of which he makes his glue. It is used in the manufacture of candles, glass, carbonate of soda, and gas, and during the processes of smelting and bleaching—in fact, there are many metals which could never be smelted at all but for the help of lime.

Quicklime is very thirsty stuff, and if it can satisfy its thirst in no other way, it will steal the moisture out of the atmosphere. This is called *air-slaking*.

If your father is a carpenter, or if you have a box of instruments, and you are afraid that the tools are becoming rusty, try the effect of shutting them up in company with an open jar of thirsty lime. It will keep the atmosphere dry, and the steel nice and bright, for of course you know that it is the moisture in the air that causes rust.

The doctor finds lime very useful. He uses it in some form or other in some of his medicines, and as a disinfectant. And lastly, I have no doubt that when you were a baby, your mother used it in the form of lime water to assist your bones to grow strong, and to help you to digest your milk.

CHAPTER IV

The History of Cement

The various kinds of cement may be divided into three classes:

1. Cements having for their basis some form of lime, and largely used by builders and engineers.

2. Cements made from lead or from bitumen or natural pitch, and used by engineers.

3. Cements, or adhesives as they are generally called, such as gum, glue, paste, &c.

This book deals only with the various forms of cement included in class 1.

I have shown you in the previous chapter how

A CHALK QUARRY

Digging the chalk by hand (see page 34)

some prehistoric man discovered that by burning limestone, *slaking* the lime thus produced, and using it in the form of mortar, he obtained a binding material which would, for a time at any rate, resist the action of the weather, but which, you must remember, would not *set*, or harden, under water. For example, if he wished to build a bridge or make a breakwater, such mortar would be of no use for the purpose of binding together the stones he wished to keep in place beneath the surface of the water. In other words, it was not hydraulic. Very likely, this is the reason that he never ventured to attempt such work. At all events, we have no records or remains to show that he succeeded.

The ancient Egyptians possessed the secret of making some sort of mortar or cement, for they certainly cemented together the stones of their great temples and pyramids, while the use of mortar is also shown in many of the buildings of the Greeks.

We pass now to the time of the Romans. Any boy or girl who has lived in a part of the country where there are Roman remains, and has had the chance of seeing them, must have been struck by the evidences of the builders' skill. After nearly two thousand years of neglect, sometimes, indeed, after having been buried beneath the surface of the earth, they are uncovered, and we find the floors and the walls in almost as good a condition now as when they were first made nearly twenty centuries ago. There are the stables, the kitchens, the various

rooms, and even the remains of the ovens and heating apparatus. Often we find the floors inlaid with tiles arranged in various patterns, and still in an excellent state of preservation.

Hence we may be sure that the Romans had dis-

The Pantheon at Rome, the dome of which is made of cement

covered the secret of making a durable cement of some kind. They made it by burning a suitable limestone, and then grinding the burnt stone and sifting the powder through sieves of different-sized mesh. The result was a brownish cement which varied in depth of colour with the locality and with the limestone used, the brown colour being caused by the presence of iron. You have often been told how the Romans excelled as road builders. The excellence

of their roads was due in great part, especially in the neighbourhood of their camps and other populous places, to the use of cement as a binding material.

The dome of the Pantheon was made of this cement, as were many of their baths and aqueducts.

The limestone was burnt in kilns, the remains of one of which were discovered in 1911 just outside Northfleet station in Kent. It was about twelve feet in diameter.

Let us come now to more recent times. You have all heard of Eddystone Lighthouse, and how that the first was washed away by a storm, and the second, which was built of timber, was destroyed by fire. Then Smeaton appeared on the scene with designs for a third, which he decided to build of stone. Of all buildings a lighthouse, owing to its damp, exposed position, would require in its construction a good binding material, something that would withstand the action of water. Ordinary mortar would not answer, would it? Smeaton spent a long time in looking for a suitable material before beginning to build, and he found in South Wales a limestone which, when burnt, produced an excellent *hydraulic* mortar, or natural cement. He built his lighthouse with this, and he built it so well, that it actually outlasted the solid rock upon which it stood. This is only one example of what is known as a *natural* cement, to distinguish it from the manufactured article.

We come now to the close of the eighteenth

century, when it was found that by dredging the sea bottom between Sheppey and Harwich a supply of dark-brown stones could be obtained. These stones were of varying shapes and sizes, some being about the size of a cricket ball, and others larger than a football. They contained lime and clay and a little iron. Their scientific name is Septaria, and they occur in the London clay just as flints are found in chalk.

First, men with sledge-hammers roughly broke up the stones, and then women still further reduced them to about the size of a large egg. They were next burnt in kilns of the shapes shown on pp. 16 and 17. On a grating, raised above a *draw-hole*, a supply of fuel, generally coke and wood, was arranged. Then came a layer of the broken stones, then a layer of fuel, and so on till the top of the kiln was reached. Arranged round the sides of the kiln on a level with the grating were three or four *eyes*, so placed that every part of the interior of the kiln could be reached by the workmen with their irons or rakes. Unless the kiln required repairing, it was never allowed to go out, and so this type was called a "*running*" or "*continuous*" *kiln*. When the stones at the bottom were sufficiently burnt or *calcined*, the eyes, which were otherwise kept roughly bricked up, were opened. That seems the proper sort of thing to do with other kinds of eyes. Then men armed with long irons drew out of the kilns the burnt stone. This was done daily, a certain number

of *crens*, as they were called, being drawn each time, and the kiln filled up again from the top. The burnt stones were then ground to a fine powder, which was passed through sieves. In this way an excellent hydraulic cement was, and is still made. It sets quickly, and is especially useful in damp positions, or where cement is needed for work below the surface of the water; indeed, for over fifty years it was the chief cement of commerce, but is very little used nowadays. It is called Roman Cement, not because the Romans made it, but because it is of a similar colour, that is, a snuff-coloured brown.

While dealing with natural hydraulic cement made from carbonate of lime, I may mention that another class of natural cement is made from sulphate of lime in very much the same way. You have all heard of plaster of Paris. That, and a cement known as Keene's, are made from this other kind of limestone. The heat used in their manufacture is not as great as that used in burning the carbonate of lime. The kiln is made just hot enough to scorch white paper. These two cements set very quickly, and can even be brought to a polished surface.

Natural cements have been practically superseded by what is known as Portland Cement, the manufacture of which has assumed such importance.

Remember, natural cements are made by burning the impure limestone *alone*, while artificial cement is made by burning a *mixture* of clay and chalk, or of limestone and shale.

CHAPTER V

Artificial Portland Cement

You will no doubt know that the history of the world is divided into what are known as "ages". Thus we have the Stone, Bronze, and Iron and Steel Ages. We may say with some truth that we have now come to the Cement and Concrete Age, for many of the greatest engineering feats of modern times could never have been carried out without the use of artificial cement, or of the concrete which is made from it.

Whenever we hear of a great invention or an important discovery, we like to think that it is the work of one of our own countrymen. You will therefore be glad to know that artificial cement was the invention of a Leeds workman named Joseph Aspdin, in the year 1824. He mixed chalk and clay in certain proportions, and, by a new process, produced what he called Portland Cement. He gave it this name because, when set hard, it resembled the building stone which is quarried at Portland in Dorsetshire, and used so extensively in many of our most famous buildings—St. Paul's, for example.

For some time Aspdin worked at the production of his cement in Wakefield, but soon the new process found its way to a new and permanent home on the banks of the Thames and Medway. This was only

natural, for there, as you have learnt, you find the raw materials lying side by side, chalk under the downs and rounded hills on the banks of the Thames, and clay on the banks of the lower reaches of the Medway.

Here also there are ample supplies of fuel, and ready access to all parts of the world by means of the many steamers and sailing vessels trading from the port of London; indeed, though the production of Portland cement has grown up in many other parts of the world, and has even attained large dimensions in some countries, there is no district which possesses greater natural advantages than are found in the Thames and Medway valleys.

Artificial Portland cement has now been made for a long time, so you see that it is no baby industry either in age or development, for it is estimated that over twenty million tons are produced annually, and the quantity is increasing by leaps and bounds as fresh uses are discovered to which it may be put. The capital invested in the industry amounts to many millions of pounds sterling. It has been said that the two great discoveries of the nineteenth century were Bessemer Steel and Portland Cement.

I have told you that the cement of the Romans possessed very lasting qualities, but the artificial Portland cement made to-day is practically imperishable. Sometimes steel and iron are embedded in it, forming what is known as *reinforced concrete*, the effect of the steel being not only to strengthen the concrete,

but to make it more elastic. Later on I shall show you some of the very novel uses to which this reinforced concrete is being put. It would appear that this method of using Portland cement is becoming more and more popular, so that it is certain that the output will have to be extended very considerably.

In some parts of the world, notably in Belgium, Nature herself has taken a hand in mixing chalk and clay in a rough-and-ready way, and presenting us with what we might consider a very good ready-made mixture, from which is made and exported to us an article which is really natural cement, and not *artificial* Portland cement at all. In this respect Nature has proved herself for once unreliable and inefficient as far as the production of the latter article is concerned, for the proportions of the ingredients in the natural mixture vary so much, and their composition is so uncertain, that cement made from it cannot be depended upon. The cement chemist of to-day is more careful, and so much more accurate, especially in the early stages of the process, that in this matter, if in no other, his work is superior to that of old Mother Nature.

Let us now visit a cement factory of a modern up-to-date type, and see how the chalk is quarried from the hills, and the clay dug from the river banks, and both together turned into the cement of commerce.

DIGGING CLAY BY HAND (see page 39)

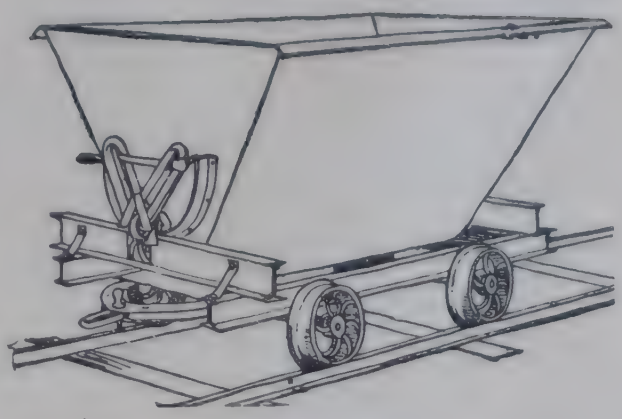
CHAPTER VI

The Chalk Quarry

Let us suppose we have before us on one of the rolling Kentish Downs a green field which has been given over to the cement maker for chalk. He knows perfectly well, both from experience and by practical tests made by boring, that beneath the grass there is a supply of good chalk.

First there arrives on the scene a gang of men who set to work to remove the top soil. If possible, they commence at the lowest level of the field, and work their way gradually towards the higher parts. With their picks and shovels, or sometimes with huge crowbars, they remove enough of the soil to allow a start to be made on the chalk as soon as possible. As the chalk is worked back, the removal of the soil keeps step with it, so as to allow the *chalky*, as the labourer who quarries the chalk is called, to work continuously, for the kilns in the factory are never idle, but are always clamouring for more and more chalk. The local name for the brown top soil is *callow*, and the removal of it is called *uncallowing*. Frequently deep pockets or holes, called *pot-holes*, are encountered during the course of the work. They have been formed by the action of water sinking through the soft chalk, and all are tapering or carrot-shaped. They are filled with gravel, sand, clay, or soil, which-

ever happened to be near when they were formed.



A Tip-truck

Those who are engaged in uncallowing need to exercise great care and judgment. On the surface of the chalk which they have uncovered they lay their temporary rails, along which they run their *tip-trucks* to a suitable *tip*, which must be in such a position as not to impede in any way the path of the trucks laden with chalk passing to and fro. Sometimes the soil is taken to an already exhausted quarry, and spread out to form what may become later on a field, a market-garden, or even a football ground.

The uncallowing gang is followed by the *chalky* and his gang. These men remove all the chalk down to the river- or sea-level. As they work their way towards the higher parts of the field, the face of the chalk becomes steeper and steeper, till at last it forms a cliff sometimes as much as two hundred feet high. Although watching the men may give you the impression that theirs is a very easy task, yet experience proves that much skill and care are required in its performance. It is the proud boast of the chalky that whilst he can take the place of any other workmen on the factory, no other man can satisfactorily take his place. Just pick up his huge *pitcher* or pointed

iron bar. It weighs 23 pounds, and is quite as much as you can lift comfortably, to say nothing of using it hour after hour at a stretch.

He stands ready for action at the edge of the chalk which has already been exposed for him. He wears a special leather belt with a hook at the back. In the hook is fixed one end of a long rope called the life-line. The other end is fixed to a convenient post at the top of the cliff, or failing a post, to a crowbar securely driven into the ground some little distance from the edge. The use of the life-line is now compulsory, for it prevents the worker from rolling to almost certain death should he lose his footing. But the chalky is very sure-footed, and rarely slips. A strong nerve, and constant familiarity with danger have bred contempt of it.

With his sharp-pointed, six-foot-long pitcher, or sometimes with his pick, he loosens and levers away the chalk, which rolls down the cliff into the empty trucks below. The chalkies are at work within a short distance of each other, and contrive, as you will see in the picture on p. 22, to make a funnel-shaped cutting or *score-way* down which the loose chalk runs. At the spot where it runs down you will notice that another cutting, narrow and of rectangular shape, has been made in the chalk just above the truck in the picture. This cutting is called the *shoot*. Suspended in the shoot is a sort of wooden flap or loose board, which serves a double purpose. It arrests the force of the falling

chalk and so prevents damage to the truck. It also stops the chalk from shooting beyond the truck. Sometimes a wooden spout is added to the shoot to ensure that the chalk shall drop exactly in the truck.

A Steam-navvy at work in a Chalk Quarry

You will understand all this better by looking at the picture of the chalk quarry.

Let us go now to the foot of the cliff or chalk cutting and watch the filling of the trucks. You will notice just under the shoot a short tunnel, and into this tunnel the trucks, one at a time, are backed along temporary rails, which are taken up and relaid as the work advances. Each truck is levered into position by a boy, generally called a *Peter-boy*, whose duty it

is to watch the filling of the wagons. When one is full he stops the flow of chalk, and the chalkies above have to wait while the full truck is drawn out of the tunnel by a horse, and another levered into position. Then the word is given and the work proceeds as before. When all the trucks are full, along comes a low squat engine specially built for the work, and hauls them off to the factory, leaving in their place more empty ones to be filled. The work goes on day and night, the only thing that seems to be able to stop it being a deluge. At night the scene is lit up either by electric lights on high standards, or by humble flare-lamps. Chalk digging by night is a weird scene, and one you would not be likely to forget.

The more recent method of winning the chalk is by the use of the *steam-navvy* or *digger*, one of which is shown at work in the picture on p. 35. It runs on rails parallel to the face of the cliff, and does the work of quite a number of men, and does it more quickly too. It gives one the impression of a greedy, hungry giant clawing up the sides of the chalk cliff, and clutching in one handful anything from fifteen hundredweights to a ton at a time. Then he swings round, uncloses his fist directly over a truck, and fills it at one "*go*". It is not picturesque, but it is good business. He can reach to a height of about twenty feet, and having exhausted the top chalk to that height, he starts again twenty feet lower down, and so on till there is no more to remove.

You would be sure to notice one peculiar feature of the landscape in any part of the chalk area where the making of Portland cement has been going on for a long time. The countryside has been quarried almost out of existence, leaving parts of the highroads and railroads perched, as it were, on the top of lofty walls of chalk with steep cliffs descending on either side, and tunnelled here and there to allow the truck-loads of chalk to pass on their way from the quarries to the factories.

CHAPTER VII

Clay-digging

There are two kinds of clay used in the making of artificial Portland cement—alluvial clay and London clay. Alluvial clay, which is found on the banks of the Medway above Sheerness, and on the shores of the creeks on the Essex coast beyond Shoeburyness, has been employed from the very beginning, and so I will deal with that first.

To reach the scene of operations, you must either sail down the Thames in an empty barge, or take the train and join the barge at its berth in the clay. Take my advice, and, if you can, make friends with the captain and sail down the river. There are many worse ways of spending a holiday, but do not expect much in the way of scenery.

THE WASH-MILLS (see page 44)

The barge is taken at high water to her berth and moored. Then, as the tide runs out, the vessel grounds on the clay. Nothing can be done till low water. Then the work commences in earnest. As many men as can conveniently find room on the clay alongside the barge, set to work with a special wooden spade or "spit", having a blade about seven inches wide and a foot long. This blade is half a spade and half a scoop, and is tipped with steel. As long as the tide will permit the work to go on, it proceeds uninterruptedly, for in one tide, or at the utmost two, the barge must be loaded with anything from one hundred to two hundred tons of clay. The digging can only be done at low water, and so no time must be lost.

Here again, as in the case of the chalk, mechanical digging has been introduced by means of a crane and "grab", which work at all times, whatever the state of the tide may be.

As soon as the loading is finished, and there is sufficient water, up comes the anchor, and off we go up the river to discharge our cargo at the factory.

Then there is the second kind of clay,—London clay. Here a different method is adopted, as you can see in the illustration on p. 31.

The clay is dug out by hand in much the same way as the chalk. You can see in the picture the trucks waiting beneath the shoots to be filled with the falling material. You will notice that the lines of rails all converge towards one spot. Here the truck-

loads are tipped into huge tanks of water, somewhat like the wash-mills which I shall describe later on. In these tanks the clay is washed and reduced to a liquid state, and then pumped through huge iron pipes to the factories a mile or two away, where it is mixed with the chalk.

The advantage of this method is that it saves the labour and expense of conveying the clay by barge from the Medway, and the cost of the subsequent unloading and conveyance of the cargo from the wharf to the wash-mills.

CHAPTER VIII

The Wash-mills

In a previous chapter I dealt with the origin of Portland cement, and I tried to show you that at first, the only raw materials used were always chalk and alluvial clay. I want you to notice now, that as time went on and the industry grew, other substances began to be used, such as London clay, or even shale and slate in the place of the alluvial clay, and marl and various kinds of limestones in the place of the chalk. Slag, the waste product of the blast furnaces, is also used, as it contains what I have shown you to be the necessary constituents of cement, namely, lime, silica, and alumina.

There are different ways of dealing with the various

substances which now compose the raw material, and these ways are called processes. Roughly speaking, these processes fall into two distinct heads or classes, the dry and the wet. But I want you to keep in mind that the only difference between these two methods is to be found in the first stage of the manufacture, that is, in the preparation of the raw materials.

Where the latter are extremely hard, as is the case in some of the limestones, they must first be dried and then ground between stones or in mills to a powder as fine as flour, and then the materials are mixed in the right proportions. The preliminary drying is very necessary, because, as you have very likely found from experience, it is impossible to grind damp material. Hot-air chambers, and sometimes kilns, as well as other means are employed for the purpose. The dry process is largely employed in the United States, but here in England our chalk and clay are so soft, and admit of being so intimately mixed, that the labour, trouble, and expense of the dry process is avoided, and the wet method adopted instead. Here, the dry process is quite the exception.

Now I want you to come with me round a typical, modern, up-to-date factory, and watch the wet process from beginning to end, always bearing in mind that once the washing and mixing stage is past, what you will see will apply equally well to the dry process.

I notice that you have come dressed for the occa-

sion, or rather, I should say, you are *not* dressed for the occasion. So before we make a start you had better cover up your finery with an overall thoughtfully provided by our guide, and put on the cloth cap he offers you. The fit is not guaranteed, and I can assure you that you do not look at all smart. You must turn up your trousers and let your boots take care of themselves. Then off we go.

At first we are so much interested in our novel personal appearance that it is not until we have stubbed our toes a few times against the crossing and recrossing lines of rails that we begin to think how necessary it is to look where we are going.

As we go along we notice a large block of very ancient-looking concrete, and it adds to our interest when we are told that it was made as far back as 1851, and shown in the Great Exhibition held in that year. So you see there is something very enduring about concrete, for the block looks as solid as the day it was made. It is very possible that Aspdin the younger had a hand in making the cement which was used in its construction.

Let us suppose we have now arrived at the wash-mills which are to be our starting-point. Here, as in nearly every other part of the factory, the noise is so deafening that our guide's explanations have to be given, and all conversation carried on by shouting. It is no place for whispering secrets to one another.

In the background against the white chalk cliffs, there is a long, lofty, well-lighted building containing

A CEMENT FACTORY

Showing rotary plant (see page 52)

the engines which drive all the clattering, clanking machinery we see around us. In the particular factory we are visiting, all the engines are driven by means of gas produced in a huge "plant" on the premises. The engine-room is spotlessly clean, and, unlike many other parts of the factory, quite free from dust and cement. Indeed, it is necessary to keep these engines absolutely free from all grit, otherwise there would be trouble at once. But if there is no dust there is plenty of oil, for the huge engines literally wallow in it. One thing that will strike you at once as being rather peculiar, is the fact that once they are started, they seem to require no attendants to keep them running. The room appears to be quite deserted.

Outside, in front of the engine-room, is a long raised platform about ten feet high, along which pass the trucks of chalk just as we saw them loaded and dispatched from the quarry. As each truck passes over the wash-mill it is tipped, and the chalk shot down through an opening into the basin below, where it is mixed with its own volume of water. In a very few minutes the whole train-load is disposed of and the trucks are on their way back to the quarry for a fresh supply.

The wash-mills, shown on p. 38, are arranged in three rows, or *batteries* as they are called. In the present instance each battery consists of five tanks or basins, over the first of which passes the railway platform just mentioned. Each battery is complete

in itself, and though the three are sometimes working at once, two are generally found capable of supplying the needs of the factory, while the third is being cleaned out or repaired. So you will understand that we need only follow the process through one battery, as the work done in the other two is exactly the same.

Before we follow the chalk on its journey, our guide points out to us a large tank or reservoir to the right of the wash-mills. It is out of the range of the camera and so does not appear in the photograph. It contains a yellowish-looking liquid, somewhat resembling pea-soup. This is the second of the raw materials, the clay which you saw being dug some distance off in the woods, and which has been pumped down through pipes to the factory in a liquid state ready for use. Pipes conduct the clay from this storage tank to the wash-mill into which we saw the chalk being shot. To every three truck-loads of chalk a quantity of liquid clay equal to one truck-load of solid clay is added.

If, instead of the liquid clay, the solid alluvial clay from the Medway is used, the process is still more simple, though more costly, for at the wharf it is loaded from the barge into trucks and brought to the wash-mill. Then one truck-load to three of chalk is added as before. Water is kept flowing into the basin until it forms about 42 per cent of the whole mass.

It all seems very simple, but let me impress upon you this fact. If anything goes wrong in this, the

first stage of the process, and the materials are not mixed in the correct proportions, no amount of care will put matters right in the later stages. Hence the chemist is a most important man hereabouts. You do not see him running to and fro among the wash-mills, counting the loads of chalk and clay, and testing their purity. He is steadily and methodically at work in his laboratory in quite another part of the factory. He is surrounded with test-tubes and retorts and weird machines. Hourly, or even more often if anything wrong is suspected, he receives samples of the mixture. These he tests by putting a little into a glass tube and adding a little weak sulphuric acid, which, as you know, liberates the carbonic acid gas contained in the chalk. The machine registers the volume of gas liberated. He knows what the correct volume should be. If it is too great, it means that there is too much chalk, and so orders are given to add the necessary proportion of clay. If there is too little, more chalk must be added. You see, nothing is left to chance or guess-work.

Now let us see what is happening to the lumps of chalk and the clay in the first wash-mill.

The wash-mill itself is a circular tank, built of masonry partly sunk in the ground, and is about eight feet deep and twenty feet in diameter. In the centre is a column or pier of brickwork which supports an upright central shaft. To this shaft there are fixed, like spokes in a wheel or the bars in a capstan, eight horizontal arms. The arrangement can be seen quite

distinctly in the illustration. Hanging from each arm by means of chains is a *harrow*, fitted with steel teeth or tines, so fixed that when they are worn out by constant wear and tear they can be easily taken out and replaced by new ones. Chains are used instead of a more rigid method of fixing, first that the tines can, when it is necessary, be raised clear of the flints that gradually accumulate at the bottom, and secondly to give greater elasticity to the harrows. As the latter whirl rapidly round and round, they dash the chalk to pieces, and gradually mix it with the clay and water, while the stones and flints fall to the bottom.

When the mixture is sufficiently fine, it passes through a sieve to the next wash-mill in the series, where it undergoes still further harsh treatment, until at last it is so fine that nearly all of it will pass through sieves containing no fewer than 32,400 holes to the square inch. They are so fragile that they have to be protected from the whirling stones by iron plates, and even then, constant renewal of them forms a very serious item of expense. It gives you some idea of the fineness of the mixture, if you rub a little between your finger and thumb; it feels just about as smooth as oil paint, and would have very much the same appearance. This semi-liquid is called *slurry*, and is forced by means of very powerful pumps through pipes to another part of the works to be calcined or burnt. That is the second stage in the manufacture. The small

buildings to the right of each battery are the pump-houses.

As we follow the slurry to the kilns we are told a few of the uses to which the flints are put. You will note that nothing whatever is wasted. About once a week, oftener if necessary, the wash-mills are in turn stopped, and the flints removed. Many of them, coated with chalk and clay, are taken away by the cartload and used as a foundation in road-making. Others are washed and used just as they are for making walls, while some are "dressed" and utilized in building churches, &c. From what you know of the nature of a flint, you will agree that such buildings must be everlasting. You have heard of the proverb, "as hard as a flint". When ground up into powder they are used in pottery and glass-making. In the days before the introduction of matches, our great-grandfathers used them to strike sparks from, and so set light to their tinder. We also find them in the old-fashioned flint-locks of guns. Lastly, as we shall see presently, they are employed in grinding cement.

CHAPTER IX

The Kilns

The next step in the process is to burn the slurry in kilns and so turn it into *clinker*.

Formerly the slurry was dried and made up into bricks or blocks, which were burnt; but the commoner method was to pump it into large reservoirs or "backs", where it was allowed to stand till it settled. Then sluices were opened and the surface water allowed to drain off. At the same time some of the moisture was absorbed by the earthen floor and sides of the "backs". When it had dried into a comparatively plastic condition and could be handled, it was dug out and placed on the sides of the "backs", to dry under the influence of the wind and sun. It was then laid on drying-floors, where the remaining moisture was driven off, and the lumps were ready for burning.

An early Kiln built by William Aspdin

In the early days of the cement industry this was done in the same two classes of kilns that I described when I explained the different methods of burning lime. A picture of a kiln used in Kent by William Aspdin, the son of the inventor of Portland cement, is shown on p. 49. It gives you an excellent idea of what these kilns were like. They were sometimes called "bottle" kilns from their shape. The rounded part at the top is the chimney to carry off the fumes. You can see the iron bands round it to prevent it splitting from the great heat. The "eye" is for loading the kiln with raw material and fuel. The lower part is the kiln proper, in which you see another "eye" through which the burnt clinker is withdrawn.

This class of kiln wasted a great deal of heat, and so the next improvement was to remove the chimney and pass the heat through a large chamber, and thence through flues to a chimney which carried off the smoke and fumes. This is the general principle on which a chamber kiln works, but of course they vary very considerably in construction.

This kiln is loaded with dried slurry ready for burning, and liquid slurry is pumped over the floor and roof of the drying chamber, and sometimes even to a higher floor still. Then the kiln is fired, and the heat from the burning mass passes through the chamber and dries the slurry ready for the next burning. This method does away with the "backs" altogether, and saves both time and labour.

The burning takes about five days, but the time varies with the size of the kiln, some holding only ten tons while others might hold as much as fifty. When cool enough, the clinker is drawn from the kiln and taken in trucks or barrows to the grinding mills.

Gradually other types of kilns have been introduced, such as the Hoffmann and the Aalborg, until we come to the modern Rotary or revolving kiln, which is in use in the factory we are visiting. Here there is no need to pump the slurry into "backs" or heated chambers, and load it when dry into kilns. Nor is there any need to wait nearly a week for the clinker. The liquid slurry goes direct, just as it comes from the wash-mills, into one end of a long revolving iron tube —for that is what a Rotary Kiln is—and in one hour there has come out at the other end from two to three tons of clinker, uniformly and regularly calcined. Think of the time, labour, and expense that are saved!

The rotary kiln, which has made this tremendous change in the process of cement-making, is, like Portland cement itself, the invention of an Englishman. In the year 1885 it was patented by Frederick Ransome, though others had previously experimented with the idea. His first furnaces were only about thirty feet long and five feet in diameter. They were heated by gas, and instead of being fed with liquid slurry, dry materials, coarsely powdered, were used. At first, chiefly owing to difficulties in the method of heating,

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they were not a success. However, in time, the size of the kilns was greatly increased until they now reach 200 feet in length and 10 feet in diameter. Improvements were introduced, and other kinds of fuel, such as oil and powdered coal, were used, until at last, in the United States, the rotary kiln has ousted the ordinary chamber kiln, and is also being used to an increasing extent in England.

The illustration on p. 43 gives a bird's-eye view of a rotary plant. To the right you will see a huge tank filled with slurry, which has been pumped from the wash-mills. It holds a mere trifle of 10,000 tons. Day and night a moving bridge, supported by the side walls and a long brick pier in the centre, travels backwards and forwards along it. It takes about twenty minutes to go from one end to the other—rather slow travelling in these hurrying days. As it moves, four arms hung from the framework, two each side of the pier, keep turning round, in and out, stirring up the slurry, and preventing it from settling before it reaches the kilns. Nearer the latter are four or five circular tanks with bridges, which are kept revolving by means of the pressure of the slurry on the moving arms below. The object is to keep the slurry quite fluid.

Powerful pumps lift the slurry to a long gutter or channel running the length of the "plant", outside the ends of the kilns, of which in the present instance there are sixteen, looking for all the world just like sixteen huge cannon. Opposite the end of each kiln

there is an interesting little arrangement for lifting the slurry out of the channel and feeding the kiln with it, just as though the huge tube were an overgrown, hungry baby.

On p. 56 you have a section of a Rotary Kiln Plant. You will see that there are two long tubes. The higher and longer one on the right is the kiln itself, while the lower one on the left is the cooler, so called because it is here that the hot clinker is cooled after emerging from the kiln in which it is burnt. Neither tube is quite horizontal, the slight slope allowing the slurry to flow from the point *a*, where it is pumped in, down through the kiln. From thence it passes, white hot, into the cooler, and finally comes out at *d* in the form of cold clinker. The necessary heat is obtained from finely-powdered coal. At one end of the building, not shown in the illustration, there is a mill in which the coal is ground. Leading from this mill is a channel containing an endless screw or "worm", which, as it revolves, forces the fuel along into hoppers placed opposite the lower or "firing" end of each kiln. You can see one of these hoppers marked *b* in the diagram. The coal is blown into the kiln by means of a powerful blast, which can be regulated as required by the attendant on the firing platform. This fine coal bursts into flame, and develops tremendous heat the moment it enters the cylinder. You will also note on the right of the illustration the short chimney which carries off the fumes produced by combustion. Notice that, at in-

THE ROTARY KILNS

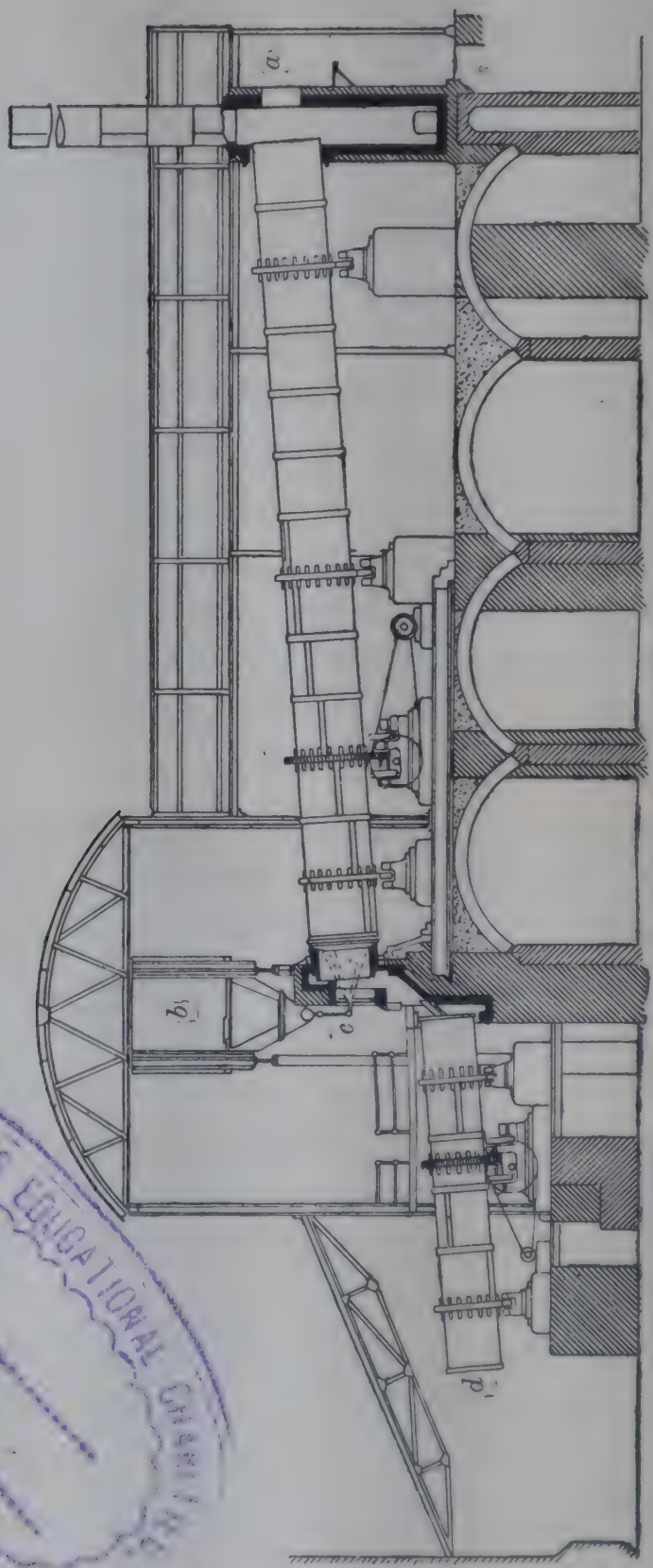
THE ROTARY COOLERS

tervals along their length, the kiln and the cooler are supported on running wheels to prevent sagging. There are also horizontal wheels, which, while they do not retard rotation, prevent the kiln from slipping bodily in the direction of the cooler, and also keep the latter from making its way out of the building altogether.

In the arched spaces beneath the kilns are the engines and dynamos for driving the various parts of the machinery, and for generating the electricity for lighting the factory.

One man can attend to two or even three kilns. He is able to control the supply of both fuel and slurry, and to regulate to a nicety the speed at which the huge tubes rotate. If the clinker comes out soft and not sufficiently burnt, it means that it has not been in the kiln long enough, and so the speed is reduced. If it is too hard, the speed is increased. This ease of adjustment is a great feature of the rotary kiln. Another point is that neither ashes nor partly-burnt fuel mix with the clinker.

The tubes revolve on an average about once a minute. Inside they are lined with fire-bricks, and are fitted with four or five iron plates running lengthwise, so that, as the slurry runs down by the force of gravity, it is thrown by the rotation of the kiln from side to side, and thus every particle is uniformly calcined by the heat from the powdered coal blown in at the other end. The heat is tremendous, and the glare, when the door is opened, so blinding, that we can only look into



Section of a Rotary Plant

B. A. N. M'S LOHIGA TIONAL CENTRE
No.
Date
BANGALORE.

the glowing mass through a violet-coloured glass. You know that the temperature of boiling water is 212° F., but at the lower end, where we are standing, it is 2800° F. So we move off to the more reasonable atmosphere of a lower platform, where we can watch the *coolers*, or tubes through which the burnt clinker passes after leaving the kilns. They, too, are revolving slowly, but are not heated, so that by the time the clinker reaches the lower end, it is quite cold, and looks like small cinders, never larger than a hen's egg.

It then drops into a hopper below *d*, which passes it into a large truck. An electric motor runs alongside, draws out each truck as it is filled, and hauls it along to a lift, which conveys it to the grinding-mills to the left of the diagram. This brings us to the end of the second stage in the process.

CHAPTER X

The Grinding-mills

We arrive now at the third and last stage in the process of cement-making.

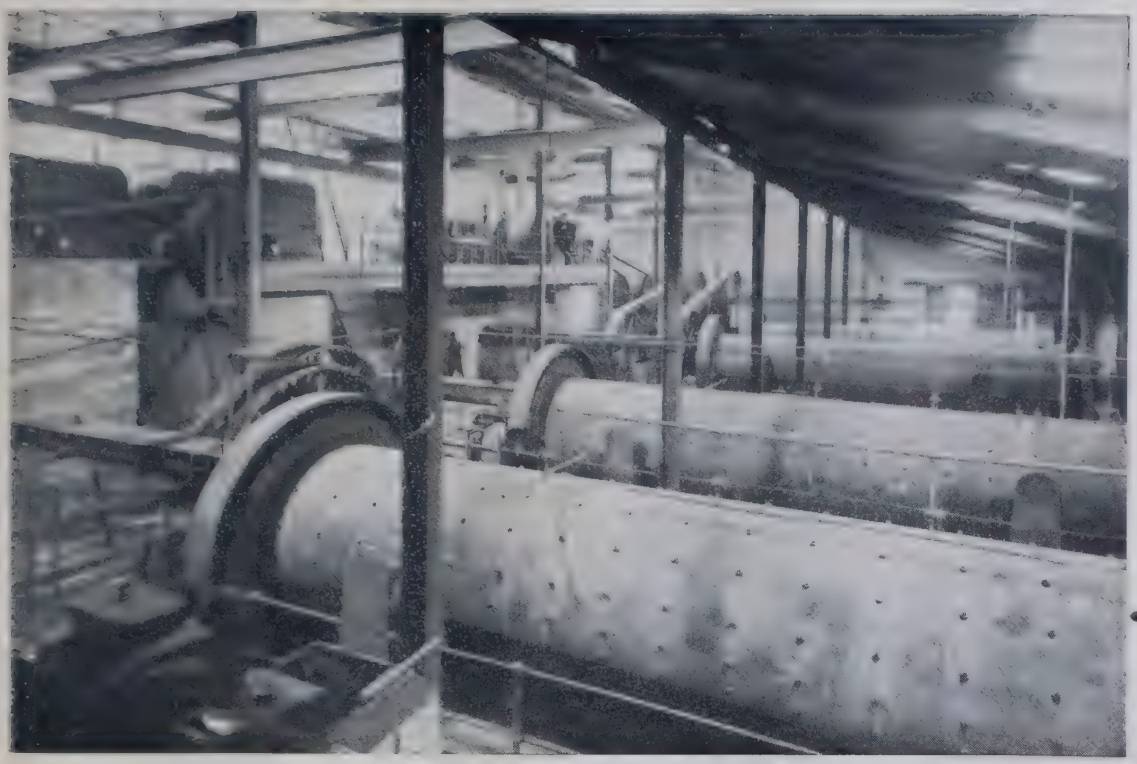
In the old days of the chamber kiln the clinker was ground between millstones. This proved a very difficult and expensive process. Moreover, to some extent it was not efficient, and the cement which was turned out by it would never have passed the

severe tests of to-day. Cement then was considered quite fine enough if 90 per cent of it would pass through a sieve containing 2500 meshes to the square inch. Nowadays, 82 per cent must pass through a sieve with 32,400 meshes to the square inch. The necessity for this very fine grinding, and the hardness of rotary-kiln clinker as compared with the chamber-kiln product, have together quite cleared millstones out of the modern factory. The difficulty has been for many years to find a good substitute, but that difficulty has now been overcome, and the grinding is carried on in huge cylinders containing steel balls or hard round stones which pound and crush the burnt slurry to a fine, flour-like powder.

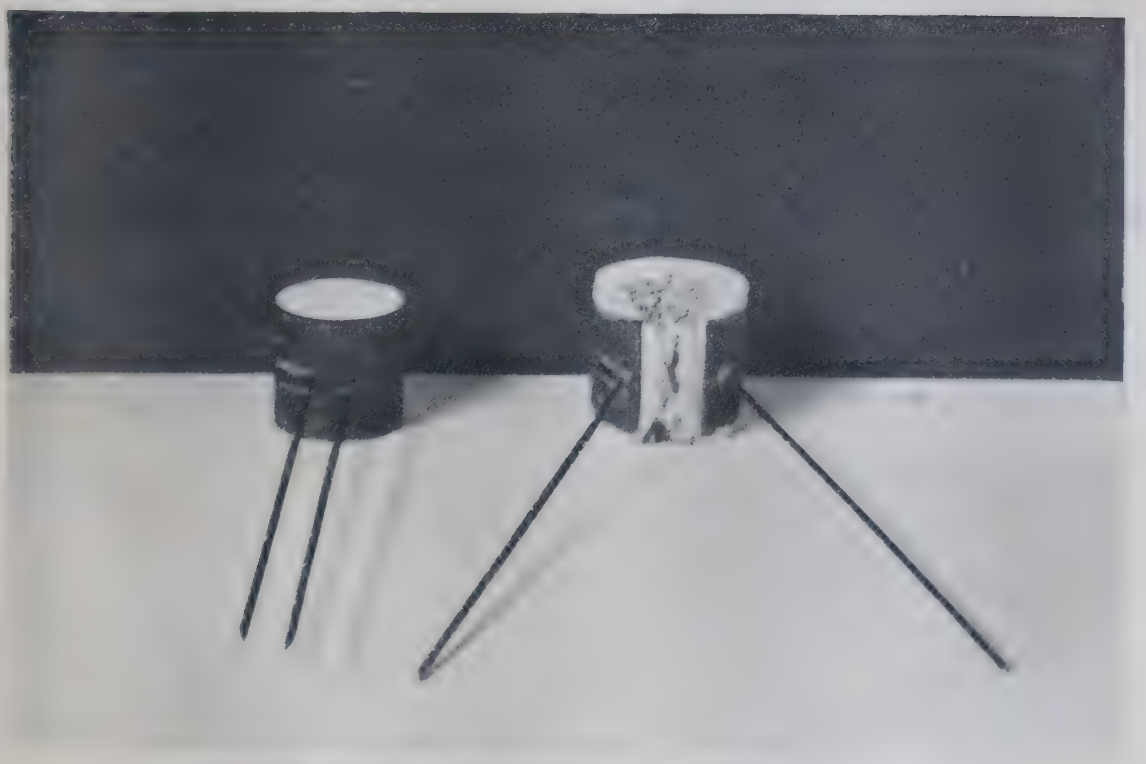
After this short explanation, let us follow the clinker into the grinding-room, or mill as it is called. If the noise at the wash-mills was bad, what shall we say about it here? The best thing is to say nothing, for you certainly would not be heard. Conversation has to be carried on by signs.

The first thing you will notice is that the mill seems to be filled with slowly rotating tubes, some short and fat, and the others long and thin. We might really say that that is the long and short of the grinding process, for after the clinker has been first through a short tube and then through a long one it enters the world as cement. So, you see, the grinding process is a double one.

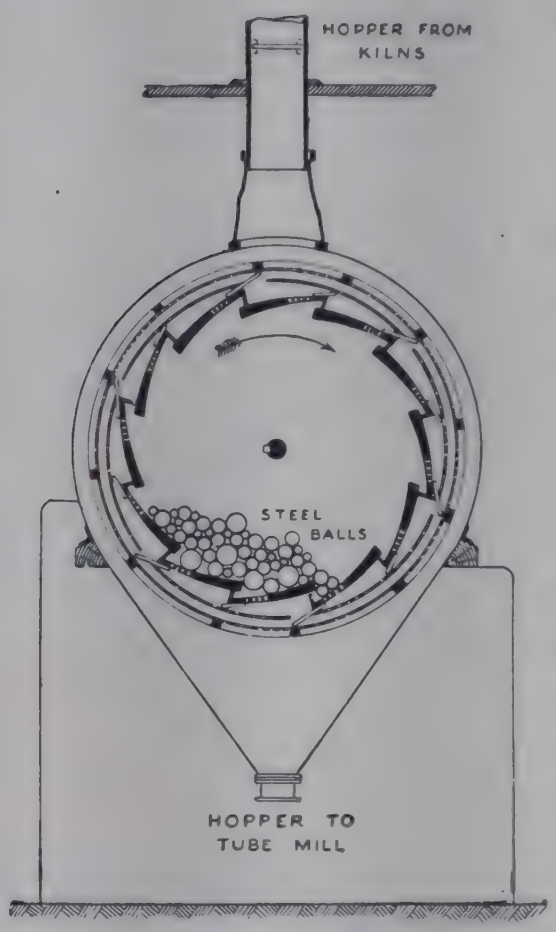
The short tubes, or mills as we ought to call them, are about 8 feet in diameter and 8 feet in length,



THE TUBE MILLS



THE "LE CHATELIER" APPARATUS (see page 70)

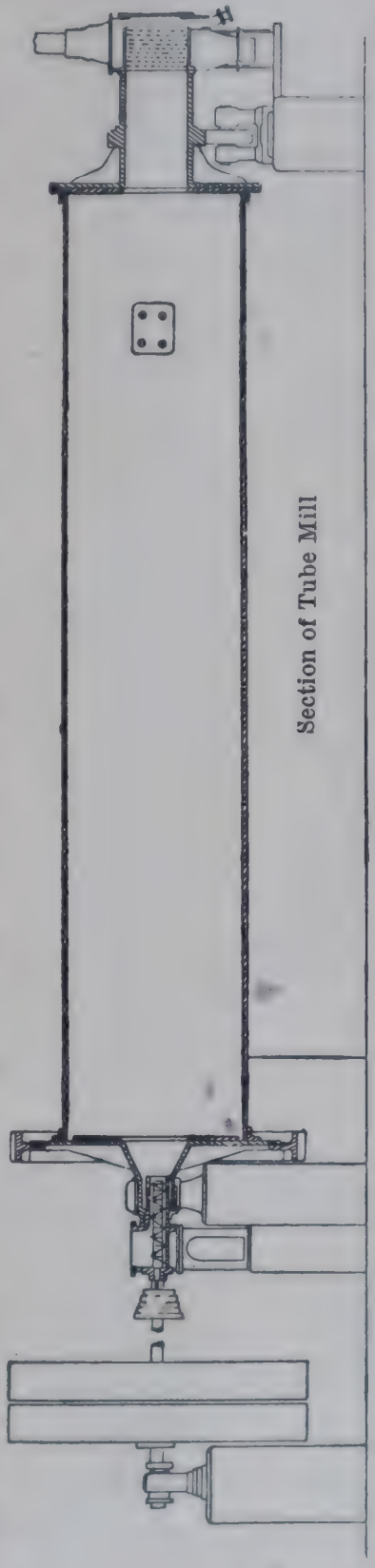


Section of a Ball Mill

and contain about 3 tons of steel balls. Thus they get the name, Ball Mills. They are fitted inside with a series of steps something like a tread-mill. The grinding is effected by means of the balls, which roll on the lower part of the mill, and fall from step to step as the mill revolves, thus crushing the clinker. There are holes in the steps which allow the crushed particles to pass through to sieves. If the powder is fine enough it passes through the sieves and into one of the long tubes. If it is not fine enough, it is returned to the ball mill and crushed still further. The illustration above, showing you the section of a ball mill, gives you a better idea of the position and action of the steps and sieves than I can give you in words. The cement falls into a hopper, and then passes on to the second stage in the process of grinding. This is effected in the Tube Mills.

The tube mill, of which the section on p. 61 gives some idea, is 26 feet in length, and only 5 feet in diameter. It is charged up to about the centre

with hard quartzite pebbles specially brought from the French coast. As the tube revolves, the cement has to undergo still further crushing and rubbing by the falling stones, until it is reduced to the necessary degree of fineness. This is regulated by the speed of the feed to the mill. The slower the coarsely-ground cement is fed in, the longer it is in the mill, and the finer it is ground. This is a very important part in the manufacturing process, and at the same time it is very costly.



You are aware, of course, that when the cement is mixed with water, it loses after a time its plastic nature and gradually becomes harder, until at last it is as hard as stone. In other words, it "sets". The very finely ground cement which comes from the tube mill would set almost at once, and so would be practically useless for building or any other purposes. So it is necessary to "retard the set", or

in other words to make it set more slowly. This is done in two ways. While the clinker is being fed into the ball mill, there goes in with it a small quantity of gypsum, which is ground with it, and mixes with it. Pure gypsum looks very much like irregular pieces of loaf sugar, and is used in the manufacture of plaster of Paris. The set is still further retarded by injecting steam into the tube mill, so that the cement undergoes its final grinding in a very moist atmosphere. This is called *hydration.*

It is curious to notice the effect of grinding upon the colour of the material. Upon a table lies a little heap of clinker, another of the coarsely-ground cement as it leaves the ball mill, and a third of the finished cement from the tube mill. You can see very plainly that the finer the cement is ground, the lighter it becomes in colour.

The cement is now quite finished, and nothing remains but to pack it in bags if it is for home consumption, and in specially made casks if it is to be sent abroad.

But before a particle of cement leaves the works, samples of it are mixed with water, and made into small cakes or *pats*, which are allowed to harden or set. These pats are then subjected in the laboratory to very severe tests, of which permanent records are kept. It is no use going to a manufacturer some months or even years after you have used his cement, and saying to him, "Look

here, the cement you sold me on such and such a date was very poor stuff." The chemist will in a moment fetch you the sample pat of the very cement you have been condemning, and will show you, written on its face, its character as proved by the tests it has undergone. So a visit to the laboratory and to the chemist in charge of it is necessary now.

CHAPTER XI

The Laboratory

Before any cement leaves the factory, it is subjected to the most stringent tests, some of which are chemical, and some mechanical.

The chemical tests deal with the *composition* of the cement. For instance, the proportion of lime has to be ascertained. If there is too much, the cement will be rejected on the ground that it will not prove lasting. The grey colour of cement is due to the presence of a little iron. Without it, cement would be white. A little iron and magnesia are no disadvantage, but much would be harmful. So the chemist has to see to it that the quantities are not excessive. He has also to determine whether silica and alumina are present in their correct proportions, for if there is too much alumina or too little silica, the cement will not have the necessary binding strength. By this time you will

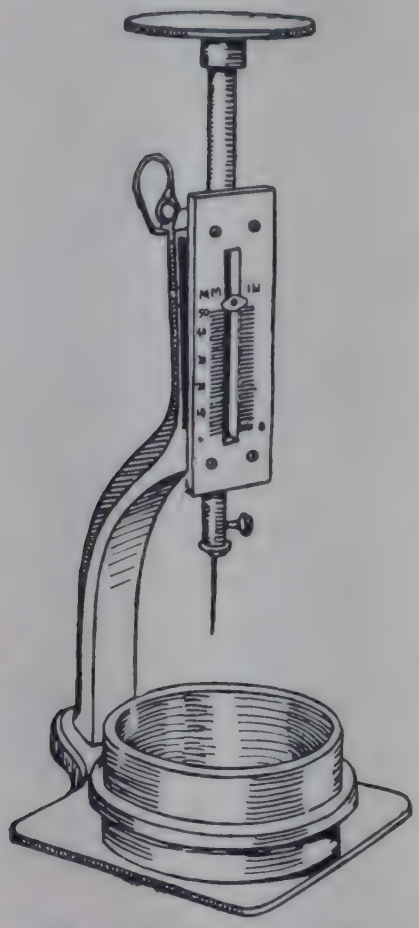
have grasped the fact which I dealt with in the chapter on the Wash-mills, that any error in the composition of the cement must be put right during the mixing of the raw materials.

The mechanical tests deal with the *strength* and *behaviour* of the cement under certain conditions.

First of all the chemist deals with the time it takes cement to set, that is, to lose its plastic nature after having been mixed with water. His plan is very simple indeed. He makes a little pat in the method shown in the previous chapter, and throws it on a glass plate, where it settles into a mass two or three inches across. Then at intervals, perhaps of five minutes each, he places on it a specially constructed "needle" of a definite weight, with a "point" of a definite area. The illustration on p. 66 shows what this needle is like. At first, while the pat is soft, the needle enters some distance into it. But gradually the needle finds more and more difficulty in entering, till at last it fails to make even an impression. This happens when the cement has set. The time it takes in setting can then be easily reckoned by counting the number of needle impressions. The further hardening of the cement is another process, which takes a far longer time than we have to spare in watching it. The needle itself is an interesting little instrument, and is so adjusted and used that exactly the same pressure is put on the pat every time. You can understand how necessary this is. A rough-and-ready way of testing

PART OF THE LABORATORY

PLACING A REINFORCED CONCRETE PILE IN POSITION



Vicat Needle for testing Setting Time

the time cement takes to set is by using the thumb nail instead of the needle, but, of course, the results would not be nearly accurate enough for the chemist.

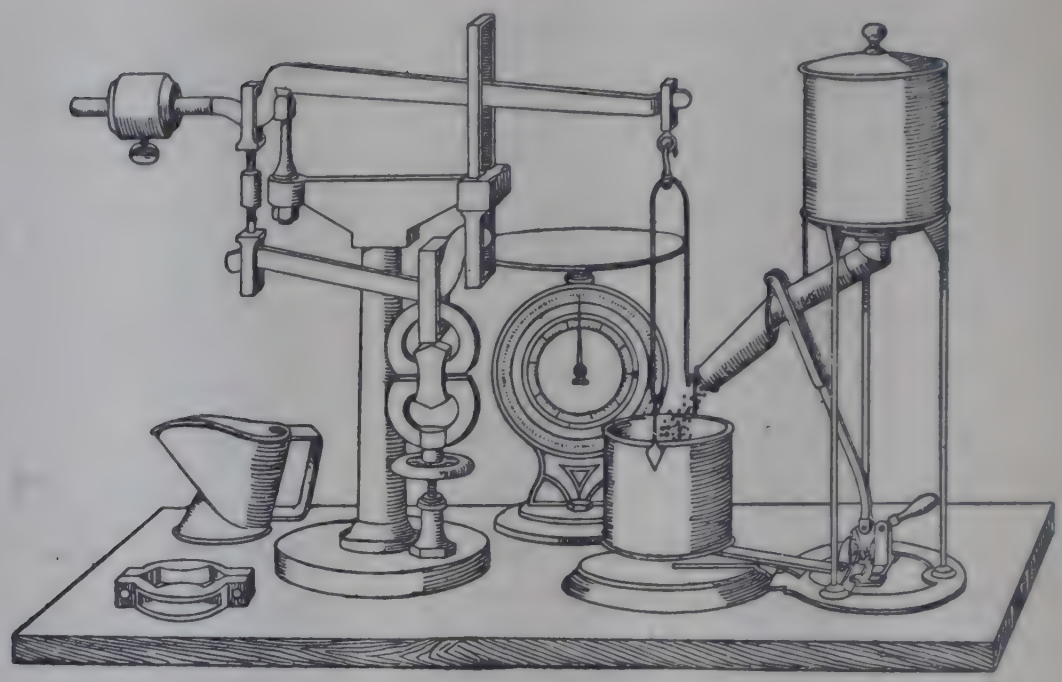
Fineness is tested by passing the cement through sieves of varying meshes up to 32,400 to the square inch, and weighing what is retained on the sieve. Other things being equal, the finer a cement is ground, the stronger it is. A builder, as you know, always mixes his cement with sand, and the very finely ground cement is better able to surround and coat the particles of sand than that which is coarsely ground. Exactly the same principle holds good in making concrete, as you will find in the next chapter.

Then the strength of cement must be tested. He deals with its tensile strength, and also with its power to resist pressure.

Do you understand what is meant by tensile strength? If you and I pulled against each other at opposite ends of a piece of paper, it would soon break, for it cannot resist a heavy pulling strain, or, as it is called, tension. In other words, paper has little tensile strength. Now, instead of the paper,

let us try a bar of iron. I fancy we should pull a long time before we caused it to break. That is because it has great tensile strength. Now the question is, what is the tensile strength of cement? The chemist soon answers the question for us. Some of the cement he tests neat, that is, without the addition of sand, while to another lot he adds three times as much sand of a special kind. He mixes the two lots separately with water, and makes them up into a number of blocks in a mould of a special shape something like the figure eight, the neck of each block being one square inch in section. A sketch of this mould is shown below. These blocks are called briquettes. They are tested under varying conditions, some after one, seven, fourteen, and twenty-eight days, or even ten years after having been made. Some are kept in water until they are needed. Testing is done in a special machine fitted with a pair of claws which grip each end of the briquette, and by means of levers pull it in opposite directions. The pull must be a steadily increasing one. There must be no jerking. In one form of machine, shot is poured into a pan until the weight causes the levers to exert sufficient strain to pull the briquette into two pieces. The moment this happens, the supply of shot is automatically cut off. What has fallen into the pan is

Briquette Mould



Tensile Testing Machine

weighed, and a scale on a dial indicates what has been the force exerted, or, in other words, what the tensile strength of the cement is. A briquette of neat cement one day old, would, if the cement was good, break between 200 and 400 lb., while one six months old, might go as high as 750 or even 1000 lb. That is not bad, is it, for what was once a piece of chalk and a handful of clay? The addition of sand, of course, reduces very considerably the tensile strength.

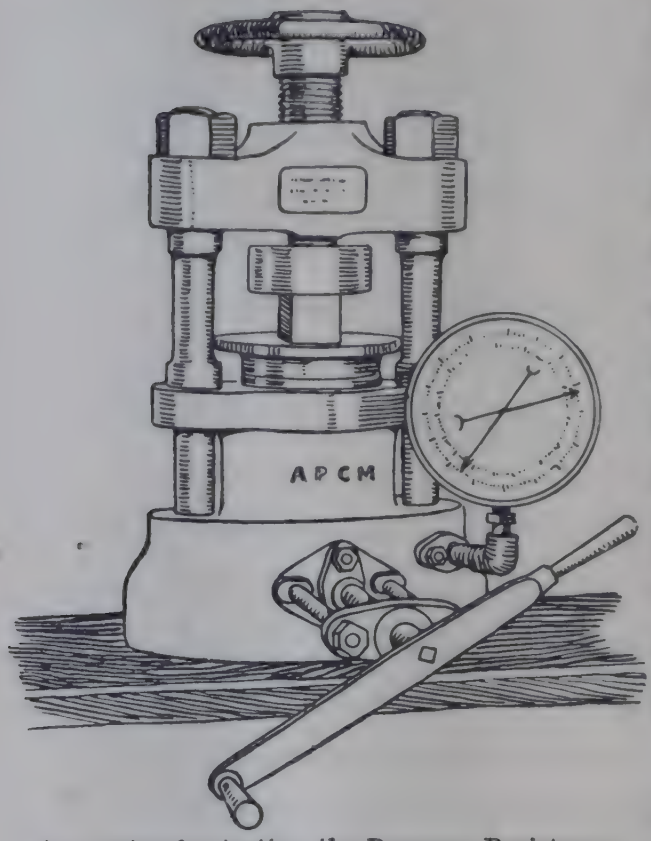
Now we must consider the strength of cement as shown by its power to resist pressure. We can very easily imagine it being used under conditions where it is subjected to very great pressure indeed; for instance, in the foundations of a house, where the tons upon tons of the dead weight of the building

rest upon it. If the foundations cannot resist the pressure, but give way under it, we might very easily find the roof in the cellar among the coals.

Suppose you place one hand upon a sponge and the other upon a flint, and press hard on them, which do you think would offer the greater resistance to the pressure? Certainly not the sponge. This little test will give you some idea of what is meant by resistance to pressure.

To test the power of cement to resist pressure, some of it neat, and some of it mixed with sand as in the previous test, is made up into cubes. After giving the cement time to set and harden, the cubes are placed in a machine like that shown in the illustration on the next page. By turning the handle, tremendous hydraulic pressure is exerted on the block. Fixed to the machine is a dial, very much like those on the automatic machines on which I have no doubt you have often weighed yourself. The instant the block collapses under this unkind treatment, a pointer on the dial shows the pressure that has been exerted.

You would think that cement which has satisfactorily undergone all these exacting tests, might now be left to go out into the world and do its work in peace. But no, it has to be tested for soundness, and this is the most important test of all. In this respect cement is very much like a human being. You, for instance, may be very strong and robust, but unless you are sound and reliable, no dependence can



Apparatus for testing the Pressure Resistance

be placed upon you. It is just the same with cement. I do not for one minute suggest that you should be boiled for a week to prove your soundness, but they *do* boil the cement pats. If they crack under this treatment the cement is not sound.

And last and most stringent test of all, a little of it is mixed with water and put into what is called the Le Chatelier apparatus shown in the lower illustration on p. 59. It consists of a brass ring which is split vertically, and on each side of the split is fixed a pointer. If the ring opens at all, the ends of the pointers very considerably magnify the extent of the opening so that it can be quite easily read. The distance between the pointers is noted on a scale, and then the apparatus, with its charge of cement in the ring, is placed in water for twenty-four hours, and brought to the boil. Boiling continues for six hours. If the cement expands at all, it forces the ring open. The distance between the pointers is again read, and if it is excessive the cement is condemned as unsound.

CHAPTER XII

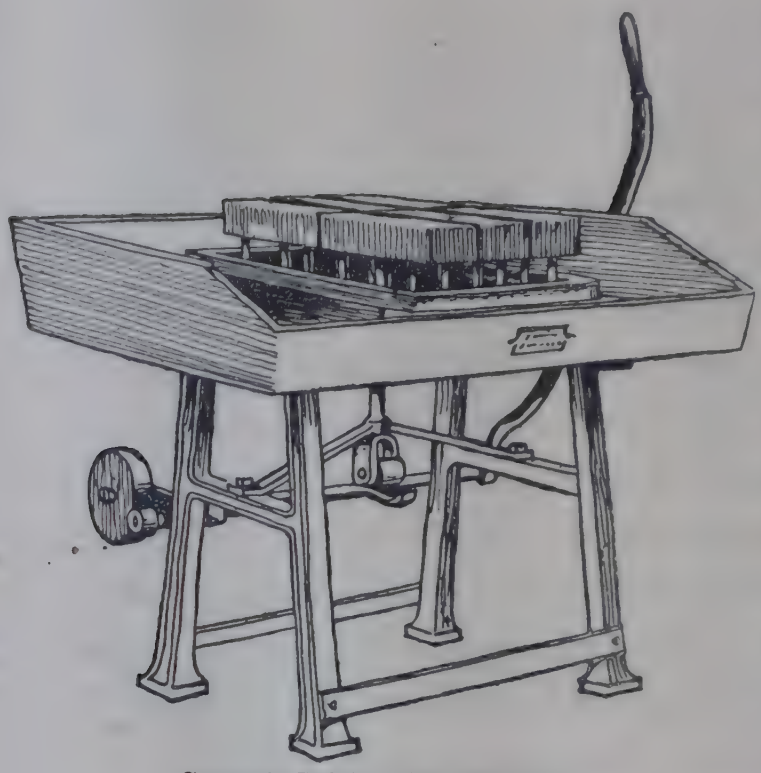
Everyday Uses of Portland Cement

In the previous chapters we have seen how the raw materials, chalk and clay, are turned into Portland cement. Let us now study a few of the ways in which the finished article is constantly being used.

In brick and stone laying lime mortar is generally used, for lime is much cheaper than Portland cement; but if the work is important, or if extra strength is required, mortar composed of cement and sifted sand is used instead. In time the cement becomes harder than the bricks and stones themselves. In the course of years lime *might* crumble, but good cement, correctly used, never will.

Sometimes cement is made into bricks and blocks, the work being done either by special machines, or by hand by means of wooden moulds. The machines will turn out from one to forty bricks at a time, or as many as 12,000 per day. An example of such a machine is given in the illustration on the next page.

Artificial stone is also made of cement; indeed, it would puzzle you very often to tell which was real, and which imitation. Door and window sills, pillars, columns, arches, steps, water-tanks, paving slabs, pipes of various kinds, in short, many of the things required by the builder are made of this material. When rein-



Concrete Brick-making Machine

forced with iron or steel in the form of rods, strips, or wire netting, it is put to many very novel uses, some of which I hope to show you later on.

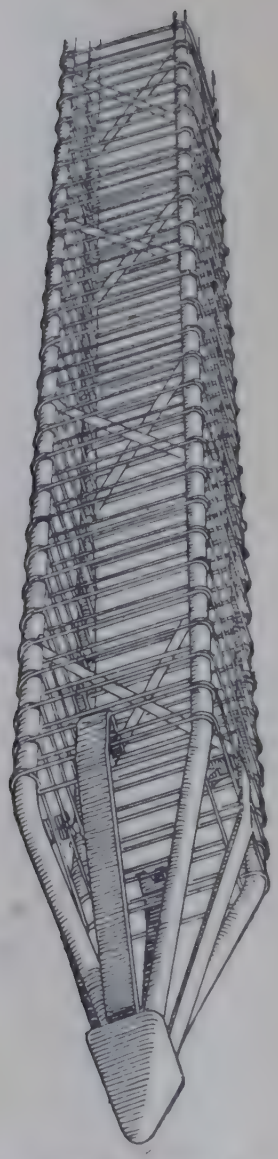
The great commercial value of cement, however, lies in its use in the form of concrete, the making of which is a matter calling for knowledge and skill if good results are to be obtained. Concrete is made by mixing together three separate materials: Portland cement, sand, and larger pieces of some hard material such as granite or gravel. The larger pieces may be as large as a hen's egg and form what is called the aggregate, while the cement and sand form a mixture called the matrix. It will help you to have a better idea of the meaning of these words, "aggregate" and "matrix", if you think of a plum-pudding. In fact, there exists a form of natural concrete which actually goes by the name of "pudding-stone". The currants and raisins might be said to represent the aggregate, and the dough the matrix, or substance in which the currants are embedded.

The proportion in which the three ingredients are mixed to form concrete varies with the work in hand. A good workman does not always aim at increasing the strength of his concrete by increasing the proportion of cement, as you might expect, but by mixing the materials so thoroughly that there are no voids between the particles. In other words, he makes his mixture as dense as possible.

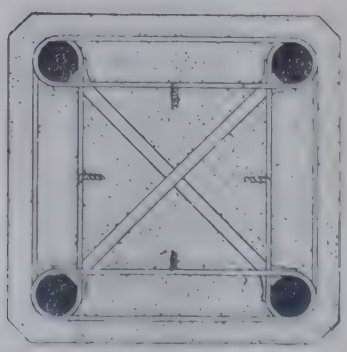
Now let us watch how this mixing is done. The sand is first measured and spread out on a board in a layer of even thickness. The cement is then spread over the surface of the sand, and the whole, while dry, turned over and over with a shovel until the grey cement and the yellow sand are thoroughly incorporated. Then the coarser material, or aggregate, is added, and the mass, still dry, again turned over. Water is now added, a little at a time, until the concrete is of the right consistency. During the addition of the water the shovel is kept going till all the ingredients are thoroughly mixed. When a large quantity of concrete is required, the mixing is done better and more quickly by machinery.

The concrete is now ready for use. It is conveyed to the place where it is to be used and gently tipped into position, and rammed with wooden or iron rammers.

Sometimes the surface is left rough, but if a better appearance is desired, it is finished off either by smoothing it with tools adapted for the purpose, or by adding a top layer of finer materials.



Steel Skeleton of Reinforced Concrete Pile



Cross-section of Reinforced Concrete Pile with Steel-work embedded

Concrete is used in a variety of ways, in fact each day seems to find some new use for it. I have previously referred to the strengthening, or reinforcing, of concrete by the addition of steel or iron.

Why should steel be embedded in concrete? What advantage is gained? Steel is strong in tension. You all know what an enormous load a steel girder will bear. Concrete is not strong in tension; a beam or floor made of it would soon break across if a heavy load were placed on it. In other words, it is brittle. You cannot depend upon brittle materials, for you never know when they may fail you. Then why use concrete at all? Why not use steel, and steel only? Steel is expensive; concrete is inexpensive. Further, steel is liable to rust if exposed to the atmosphere. So the two are used together, the concrete supplying resistance to pressure, and protection to the

steel, while the steel supplies elasticity and tensile strength.

Let us look at a few of the novel uses to which the engineer and the builder put reinforced concrete. Take, for instance, an ordinary dwelling, such as may possibly prove to be the house of the future.

Every building must, as you know, have good foundations. Sometimes the subsoil is weak and unsuitable. Quite recently we have had instances of this in the cases of St. Paul's and Winchester Cathedrals. If the builders had been acquainted with reinforced concrete, it is probable they would have built on concrete piles. In the illustration on the opposite page you see the skeleton and cross section of such a pile. You will notice the strengthening rods at each corner, and the steel strips bound round them. The skeleton is embedded in good concrete, and when quite hard is driven into position by means of a pile-driver.

When sufficient piles are in place, the foundations, also of reinforced concrete, are laid upon them. As an example, take a windmill. The rotting of the ordinary wooden foundations is always a source of danger, but in this case we might have them and the framework made of concrete, which will never rot.

The illustration on p. 78 shows you the walls in course of erection. You will notice that they are hollow. The woodwork is called the "form", and is intended to keep the concrete in place while it sets.

By permission of the Royal Liver Friendly Society

THE ROYAL LIVER BUILDING, LIVERPOOL (see page 78)

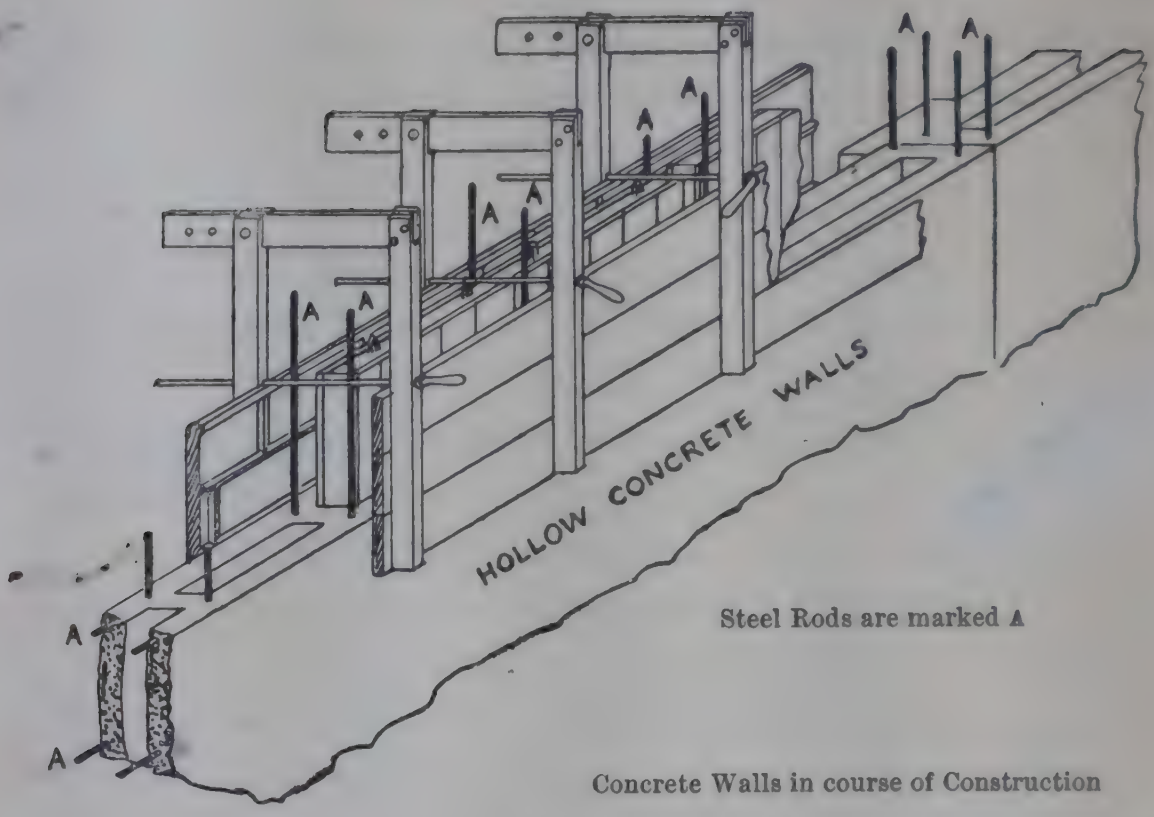
The floors and roof, as well as the paths and paving, may well be made of concrete, but instead of reinforcing the first two with rods and strips, wire netting or iron meshwork will be used instead. The paths will require no reinforcing at all. Pipes and gutters will also be of concrete, and will be embedded in the floors and paths.

The stairs, staircases, passages, and landings may be made of concrete. The steps themselves are strengthened with iron, while the ends supporting them—called the "strings"—have iron rods running lengthwise through them.

Concrete enters into the construction of pipes and sewers; in fact, a start has even been made in the direction of the manufacture in this material of some of the heavier articles of furniture, such as sideboards and cupboards.

A house built in the method I have described is practically indestructible. Perhaps you will remember that in the great earthquake which destroyed San Francisco in 1906, the buildings which suffered least were made of concrete. Another very striking example of the strength of concrete as a building material, was afforded during the earthquake in Italy in 1914, for in one of the villages that suffered most, every house but one was overthrown, and that was made of concrete. So can you wonder that day by day cement is used more and more extensively by the builder and the engineer?

So far I have only described to you the construction



Steel Rods are marked A

Concrete Walls in course of Construction

of quite an ordinary dwelling. Let us now consider something more ambitious.

No doubt you have seen a picture of New York, and have been struck by the immense height of many of the buildings. As the city is built on an island, the land available for building purposes is limited. Room for extension must be found somewhere, and so the houses, hotels, and business offices are built very much higher than ours. They tower far above our heads, so that it is very easy to understand why they are called "sky-scrapers". The great height entails increased strength of construction, and the adoption of extra precautions against fire. You can quite see how dangerous it would be to use wood. So an iron or steel skeleton is erected and encased

in concrete, the combination affording, as you have previously learned, elasticity, strength, and durability, as well as securing immunity from the risk of fire.

These huge reinforced-concrete buildings are by no means confined to the United States, though, of course, there is no necessity for us to make them as high. The picture on p. 76 of the Royal Liver Building in Liverpool shows what our own builders can do in this direction. I think you will agree that in this instance beauty and strength have been very happily combined.

Cement and concrete have, however, been brought into the service of man in ways that one would never have expected. The farmer uses it in the construction of his farm buildings, rick-stands, cow-houses, piggeries, stables, drinking-troughs, &c. It is cheap and lasting, and has the additional advantage of being clean and sanitary—very important considerations when we come to consider how essential it is that the sources of our milk supply should be above suspicion. He may even fence his fields with concrete posts. Fences and posts of wood or iron are not able to withstand for long the action of the weather. Sooner or later they decay, while reinforced concrete posts never decay. They are quite easily made in moulds, and prove very economical in the long run.

Concrete barges! Yes, they really exist, and concrete pontoons, and floating docks also, and very serviceable they have proved, while concrete blackboards, tombstones, and statues are in use!

Each day sees additions to the number of novel ways in which this useful material may be employed. No wonder we call this the "Cement Age", for it is to Portland cement, the offspring of two very humble parents, chalk and clay, that we owe such marvels of the engineer's skill as the harbour works at Dover and Gibraltar, and the barrages on the Nile at Assiout and Assouan.

Our frontispiece shows one of the locks in the Panama Canal in course of construction, and gives you a good idea of the stupendous nature of the work. The massive walls are made of concrete, as are the various wharves, piers, embankments, electric-stations, control-houses, &c., no less than 5,000,000 cubic yards of that material having been used. It is difficult for the mind to grasp these figures, but they will serve to convince you that the Panama Canal has been made possible only by the aid of Artificial Portland Cement.

A Barrage on the Nile

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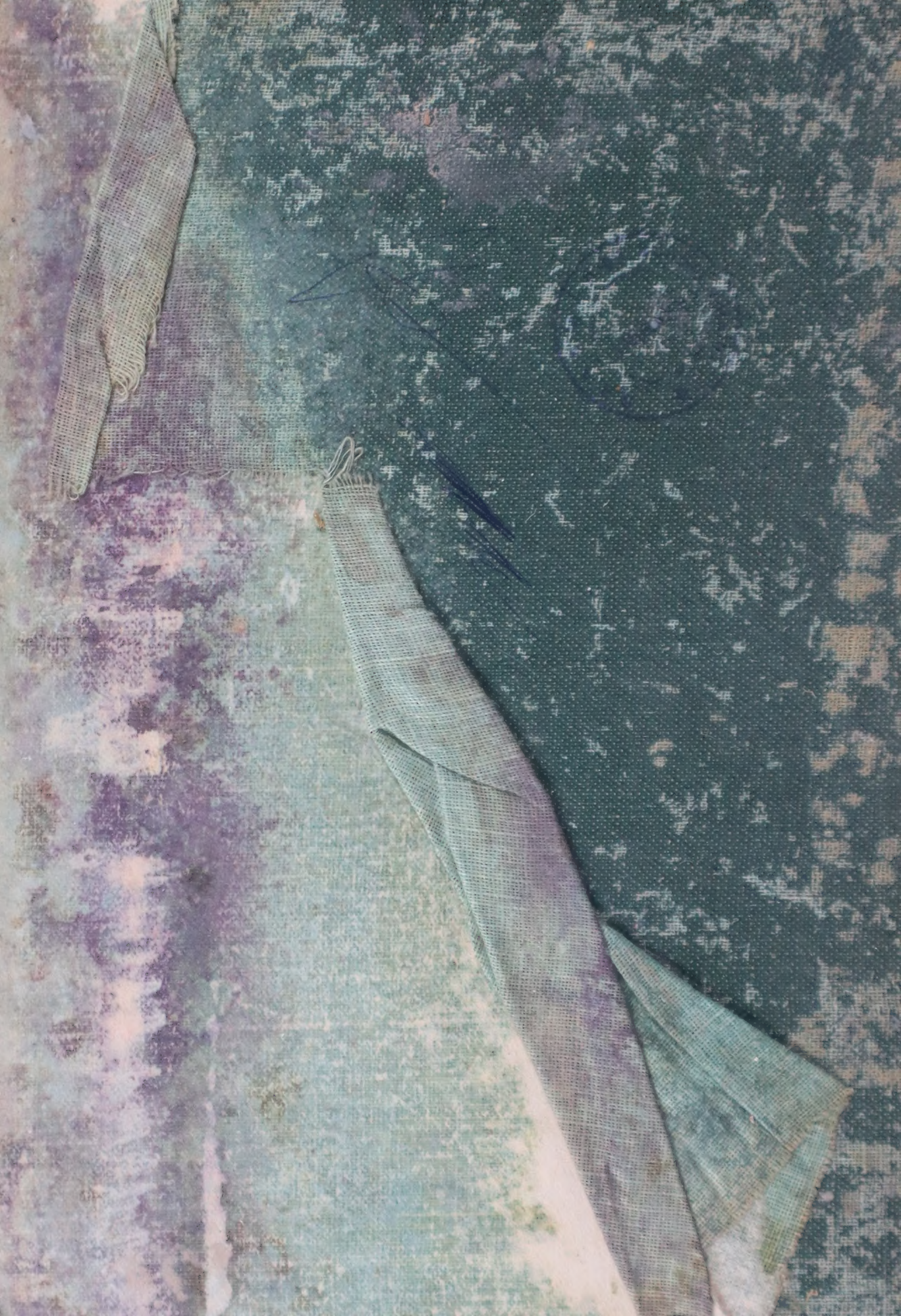
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